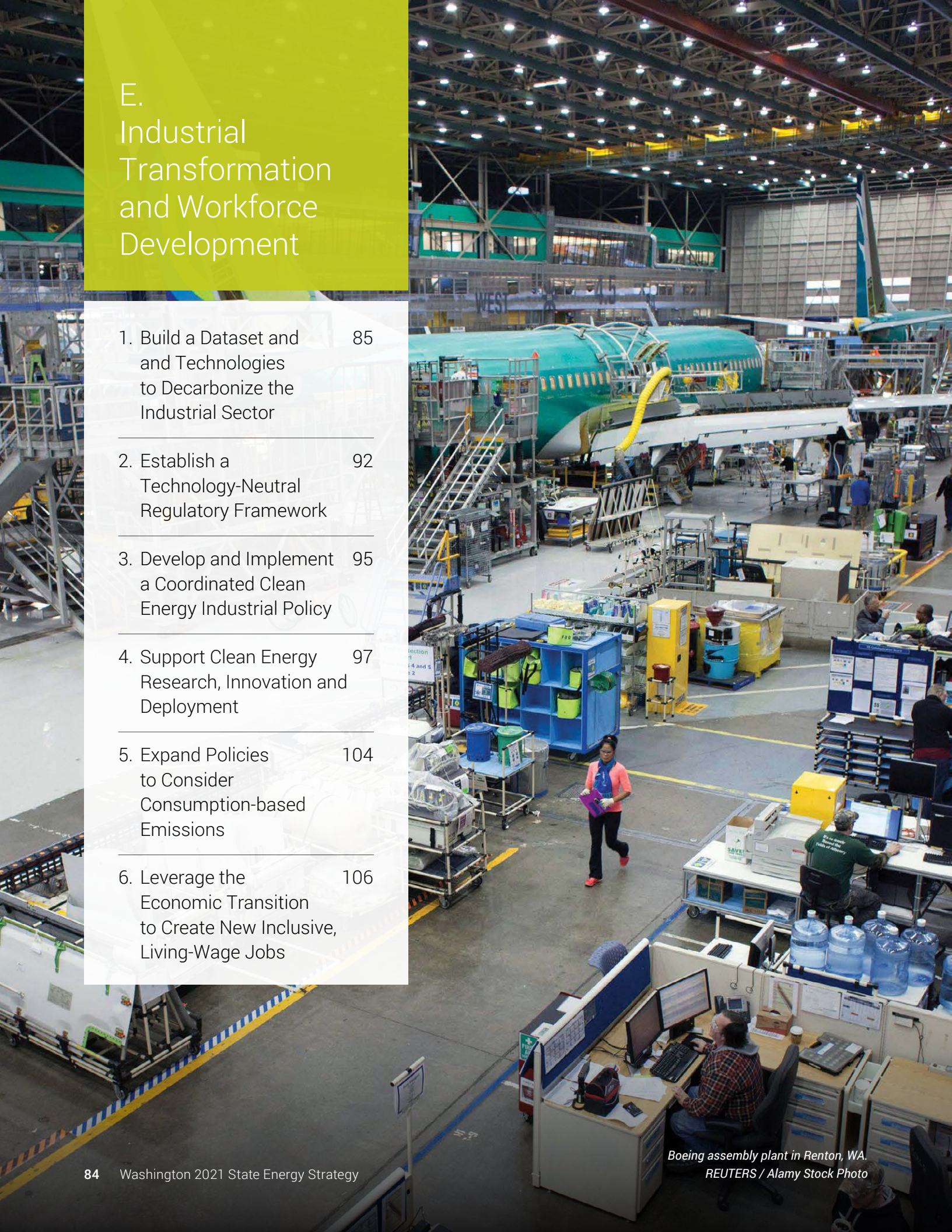
E. Industrial Transformation and Workforce Development



Boeing assembly plant in Renton, WA. REUTERS / Alamy Stock Photo

E. Industrial Transformation and Workforce Development

In pursuing a wholistic approach to industrial decarbonization, Washington can focus on areas in which it enjoys a strong competitive advantage. With low-carbon electricity, a highly skilled workforce and established advanced manufacturing industries, Washington can gain early traction in the global race to reduce the carbon intensity of products and materials.

A successful clean industrial energy policy is one that supports Washington's entire industrial sector and that takes advantage of the state's existing assets and strengths. Industrial transformation requires better information about how industry uses energy, coordination of climate policy with other jurisdictions, more attention to industrial policy and deliberate efforts to develop the skills of the state's workforce.

Energy efficient factory built housing. Chuck Murray

1. Build a Dataset and Technologies to Decarbonize the Industrial Sector

Washington's industrial sector accounts for 28% of the state's retail electricity demand[109] and about 28% of the state's greenhouse gas emissions.[110] The highest energy-consuming industries are:

- Agriculture
- Cement & Glass
- Computing Services
- Food Processing
- Forest Products
- Manufacturing/Aerospace
- Petroleum Refining

Every industrial facility and business has some potential to increase energy efficiency and reduce greenhouse gas emissions.

Industry creates greenhouse gas emissions in three ways. *Direct emissions* are the result of fossil fuel combustion for process heat, steam and hot water, on-site electric generation or space heating and are the most dominant. *Indirect emissions* derive from grid electricity consumption. *Process emissions* come from the materials in the industrial processes themselves.

Examples of process emissions in Washington include fluorinated gases used to etch semiconductors; CO_2 released from calcium carbonate during cement manufacture; and nitrous oxide emissions from degradation of fertilizers used in agriculture. These three sources of greenhouse gas — direct, indirect and process — are interdependent. Managing them presents challenges unique to each industry.

[109] "Washington Electricity Profile 2019, Table 8. Retail Sales, Revenue, and Average Retail Price by Sector, 1990 through 2019," U.S. Energy Information Administration, accessed December 1, 2020, https://www.eia.gov/electricity/state/Washington/.

[110] Washington State Department of Ecology Greenhouse Gas Emissions Inventory.

Solar power system on the new Parks, Recreation and Senior Center building in Pullman, WA. Funded in part by a grant from Commerce's Energy Efficiency and Solar Grant program. Department of Commerce

The industrial sector presents a dual opportunity for the clean energy transition: (1) efficiency and greenhouse gas reduction strategies for large-scale industrial energy consumers, and (2) development of clean technology and domestic job growth. Balancing these two, sometimes competing, opportunities will require creativity and commitment.

Industrial decarbonization roadmaps that can inform Washington's efforts include:

- **Decarbonization of the industrial sectors: the next frontier** (McKinsey & Co.)[111] *An examination that treats industrial decarbonization on a global scale and details technology options in four focus sectors — cement, steel, ammonia and ethylene — with qualitative descriptions of options without quantification of targets or potential.*
- **Transforming Industry: Paths to Industrial Decarbonization in the United States** (American Council for an Energy-Efficient Economy (ACEEE).[112] *Qualitative descriptions of options without quantification of targets or potential that includes some policy discussion*.
- **Manufacturing Agenda: A National Blueprint for Clean Technology Manufacturing Leadership and Industrial Transformation** (BlueGreen Alliance).[113] *A U.S.-focused policy analysis that includes substantial consideration of equity concerns but no technical analysis.*
- **Optionality, Flexibility & Innovation: Pathways for Deep Decarbonization in California** (Energy Futures Initiative).[114] *Economy-wide study on California with one chapter focused on the industrial sector that offers quantitative pathways to targets, on an "illustrative" level.*

[111] Arnout de Pee et al., "Decarbonization of the Industrial Sectors: The Next Frontier: How Industry Can Move toward a Low-Carbon Future" (McKinsey & Co., 2018), https://www.mckinsey.com/~/media/McKinsey/Business%20Functions/Sustainability/Our%20Insights/How%20industry%20can%20move%20toward%20a%20low%20carbon%20future/Decarbonization-of-industrial-sectors-The-next-frontier.pdf.

[112] Andrew Whitlock, Neal Elliott, and Edward Rightor, "Transforming Industry: Paths to Industrial Decarbonization in the United States" (American Council for an Energy-Efficient Economy (ACEEE), 2020).

[113] "Manufacturing Agenda: A National Blueprint for Clean Technology Manufacturing Leadership and Industrial Transformation" (BlueGreen Alliance, 2020).

[114] Ernest J. Moniz, "Optionality, Flexibility & Innovation: Pathways for Deep Decarbonization in California" (Energy Futures Initiative (EFI), 2019).

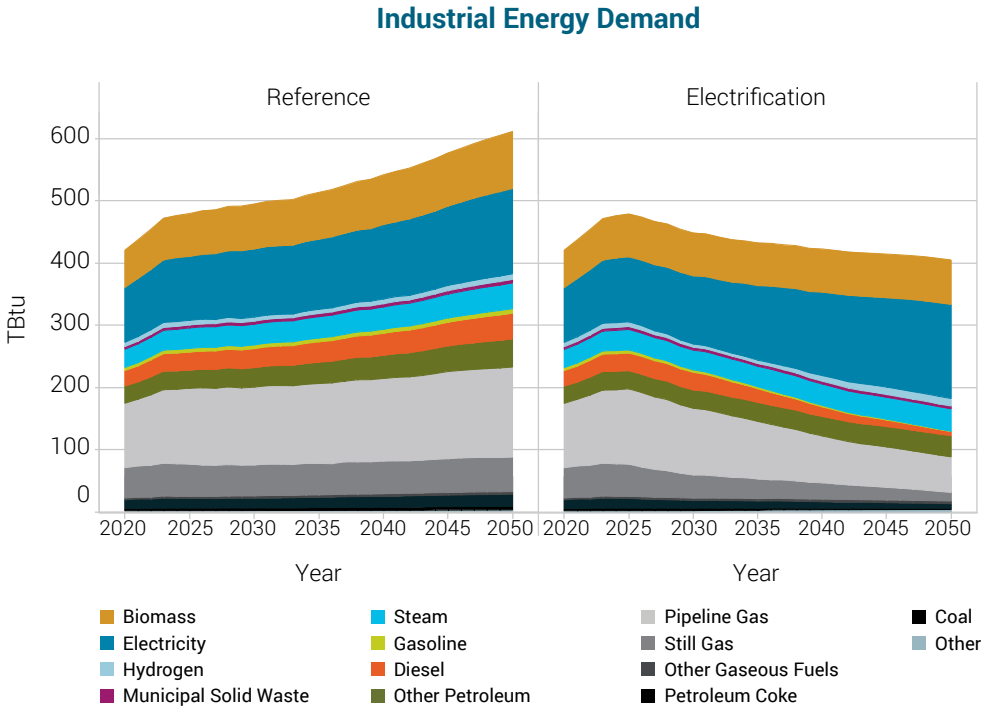
The deep decarbonization analysis did not include a detailed, process-specific model of industrial sector emissions. Instead, the model assumed that the industrial sector would increase energy efficiency by 1% each year and by 2050 could convert to electricity for 50% of process heating, 100% of machine drives and 75% of building heating and cooling. The result is a substantial reduction in total energy consumption, compared with the Reference Scenario and a substantial change in the mix of energy toward electricity as depicted in Figure 21.

Even in the industrial sector, where heat is often the most important form of energy, electrification will be critical. In the deep decarbonization modeling results, electricity replaces liquid and gaseous fossil fuels. Total final energy use in the industrial sector is 33% lower in the Electrification Scenario than in the Reference Scenario by 2050. Electricity starts at a 21% share of industrial energy demand in 2020, increasing to 36% by 2050 in the Electrification Scenario, while gaseous fuels drop from a share of 38% in 2020 to 18% in 2050.

> Every industrial facility and business has the potential to reduce greenhouse gas emissions and use energy more efficiently.

To meet the state's greenhouse gas reduction limits, Washington needs to develop a quantitative, industrial decarbonization roadmap.

FIGURE 21 – FUELS IN THE INDUSTRIAL SECTOR IN THE REFERENCE AND ELECTRIFICATION CASES



Source: Appendix A – Deep Decarbonization Pathways Modeling Report, December 11, 2020.

1.1. Build the Supporting Datasets

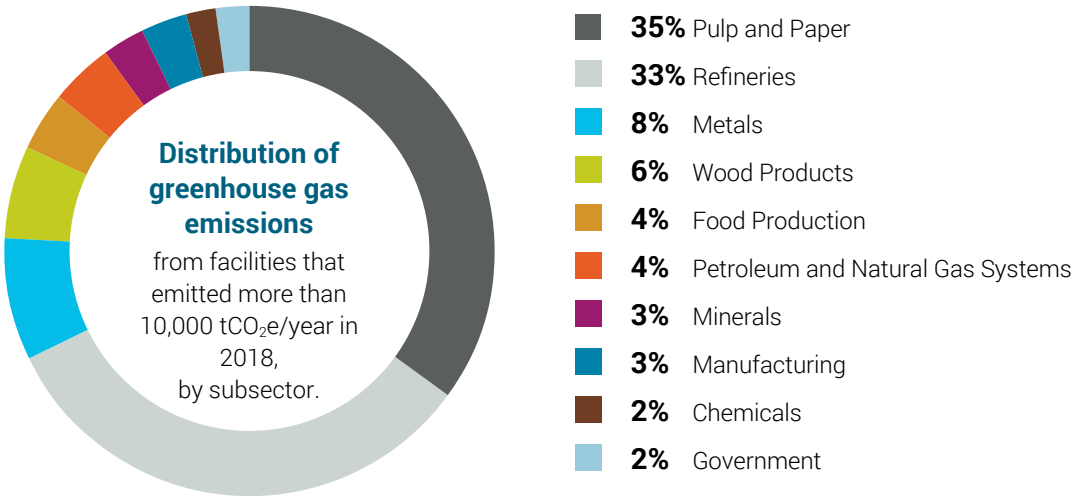
In terms of the value of goods produced, Washington's industrial sector is dominated by aerospace and data-processing activities, which account for over 54% of state industrial GDP.[115] These industries rely mostly on electricity and directly emit only a small fraction of the state's emissions. (Figure 22)

A handful of smaller industries contribute most of Washington's greenhouse gas emissions. As shown in Figure 22 and Table 3, refineries and pulp and paper facilities together accounted for about two-thirds of Washington's 2018 emissions reported by major facilities to Ecology, while those industries contribute less than 10% of the state's industrial production. Most of the emissions from pulp and paper facilities are due to combustion of biomass, considered less climatically-intensive than fossil fuel combustion because new carbon sequestration may be occurring on the harvested land.

Aluminum and steel production (metals) accounted for another 8% of greenhouse gas emissions, while lumber mills (wood products), food production and petroleum and natural gas systems account for another 4 to 5% each. These facilities produce greenhouse gas emissions from direct combustion of fossil fuels for heat and on-site electric generation, as well as greenhouse gas emissions from industrial processes, such as CO_2 from calcination of cement and perfluorocarbons (PFCs) from aluminum production.

> Electrification is a powerful tool for reducing industrial emissions.

FIGURE 22-DISTRIBUTION OF GREENHOUSE GAS EMISSIONS FROM FACILITIES THAT EMITTED MORE THAN 10,000 tCO_2e/YEAR IN 2018, BY SUBSECTOR



Most emissions from the Pulp and Paper and Wood Products subsectors are biogenic. The Metals subsector is dominated by the Alcoa Ferndale aluminum smelter, which is entering curtailment this year. The Government subsector consists almost entirely of steam plants operated by the federal government and by state institutions of higher education. (subsectors Transportation Fuel Supplier, Power Plants and Waste are excluded)

[115] As shown in Table 3, in calendar year 2018 the industrial sectors (including agriculture) had a combined gross product of $84.2 billion, of which $45.7 billion were in the aerospace and data processing sectors.

TABLE 3. WASHINGTON'S 12 LARGEST INDUSTRIAL SECTORS, IN ORDER OF 2018 GROSS DOMESTIC PRODUCT (GDP)

REMI industrial sector	GDP, mm$
Aerospace product and parts manufacturing	29,591
Data processing, hosting, related services	16,072
Petroleum and coal products manufacturing	5,452
Farm	4,263
Navigational, measuring, electromedical and control instruments mfg.	2,102
Beverage manufacturing	1,364
Fruit and vegetable preserving and specialty food manufacturing	1,227
Support activities for agriculture and forestry	1,140
Pulp, paper and paperboard mills	912
Architectural and structural metals manufacturing	858
Plastics product manufacturing	837
Pharmaceutical and medicine manufacturing	826

Source: REMI Outputs from Economic Impacts Modeling

ACTIONS

- The Department of Ecology should increase the subsector breakdown in its industrial sector greenhouse gas inventory. Both combustion and process emissions need to be broken down with the same taxonomy, so that data can be parsed meaningfully for policy-making.[116]
- The Department of Commerce should develop and publish detailed industrial sector energy data (following a coordinated taxonomy with Ecology) using federal Energy Information Administration forms data, or any new state reporting requirements.

> Washington could become a world leader in the clean energy economy, while reducing the environmental impacts of existing industries in the state.

[116] In particular, industrial sector emissions from combustion of fossil fuels must be disaggregated from the residential and commercial sectors.

Worker wrapping an HVAC air duct with foil tape. 1905HKN/iStock

1.2 Assess the Potential for Industrial Sector Greenhouse Gas Reduction Measures

There are four decarbonization approaches for the industrial sector:

ENERGY EFFICIENCY has been and continues to be the highest form of industrial environmental performance. It delivers reduced energy costs, lower direct emissions from on-site energy generation and lower emissions from grid electric generators. Energy efficiency includes lighting, building insulation and heating, ventilation and air conditioning (HVAC) solutions. In the industrial sector specifically, energy efficiency also includes efficient generation of heat and process efficiency, such as high-temperature waste heat recovery, low-temperature waste heat recovery and smart manufacturing,[117] variable-speed drives[118] and compressed air efficiency.[119]

ELECTRIFICATION is a particularly powerful tool for industrial decarbonization in Washington. As the state's utilities comply with Clean Energy Transformation Act (CETA), the electricity supply will gradually become cleaner. According to the American Council for an Energy Efficient Economy (ACEEE), typically only about 15% of the energy consumption in the more energy-intensive industries is electricity.[120]

Ample opportunity for expansion of electric consumption exists, including:

- ***Fuel-switching boilers*** allowing an industrial installation to generate steam either with a fossil fuel or with electricity;
- ***Microwave or radiofrequency*** using the same technology consumers are familiar with in microwave ovens, to more efficiently dry high-water-content feedstocks or products;
- ***Heat pumps, microwave or infrared heat*** delivering low-temperature process heat more efficiently than steam;
- ***Membrane separation technologies*** displacing boiling and distillation with the much lower-energy approach of forcing a liquid against a sufficiently fine membrane, especially in petroleum refining;
- ***Ultrasound-assisted, electromagnetic or ohmic drying*** displacing conventional oven-drying especially in food processing; and
- ***Pulsed electric field, ultra-sonification, pulsed light, UV or microwave pasteurization/sterilization*** displacing conventional pasteurization and steam autoclave sterilization, especially in food processing.

[117] Ellen McKewen, "What Is Smart Manufacturing? (Part 1A)," CMTC Manufacturing Blog (blog), accessed November 1, 2020, https://www.cmtc.com/blog/what-is-smart-manufacturing-part-1a-of-6.

[118] "Variable Speed Drives," accessed November 1, 2020, https://www.sciencedirect.com/topics/engineering/variable-speed-drives.

[119] "Compressed Air Systems," Energy.gov, accessed November 1, 2020, https://www.energy.gov/eere/amo/compressed-air-systems.

[120] Whitlock, Elliott, and Rightor, "Transforming Industry: Paths to Industrial Decarbonization in the United States."

COMBINED HEAT AND POWER (CHP). Most industrial facilities need significant amounts of both electricity and heat. CHP is a method for providing both electricity and heat on site for industrial facilities. It is the use of low-grade heat exhausted by combustion-fired electric generation, for industrial purposes.[121]

HEAT SHARING involves the transportation of heat among multiple facilities. Heat is more difficult to transport than electricity, however it is not impossible. The recent trend toward increased use of hot water or other liquid carriers rather than steam is enabling longer transport distances and reducing energy demand. But even if steam is the carrier, deliberate colocation of facilities makes transport both physically and economically viable. Heat generation benefits greatly from economies of scale, so the economic equation can favor heat sharing more than is often realized.

The suite of commercially viable technologies for increasing efficiency or reducing carbon intensity in the industrial sector is well understood and well documented. What is not well understood is the potential to lower energy consumption or displace direct fossil fuel combustion with electricity.

ACTION

- Inventory the potential associated with different technologies to provide a basis for the calculation of appropriate decarbonization targets for industry.

1.3. Lay the Groundwork for Carbon Capture, Use and Storage

One feature common among industrial facilities is smokestacks. These fixed emission point sources are potential collection points to capture carbon that would otherwise enter the atmosphere as a greenhouse gas. Captured at the emissions point, there are at least three paths to treat CO_2 that mitigate greenhouse gas emissions to a greater or lesser degree:

GEOLOGICAL STORAGE. This is the conventional vision for carbon capture and storage (CCS), in which CO_2 stack emissions are stored in underground geological formations. Initial investigations by the United State Geological Survey show meaningful potential for geological storage in Washington.[122] In addition, the Pacific Northwest National Laboratory's research is showing previously unrealized potential for carbon storage in the flood basalts common in Washington's landscape.[123]

CARBON REUSE. CO_2 captured from smokestacks can be used as a source for carbon used to produce synthetic fuels. The vehicles or other energy consumers that eventually combust the synthetic fuels still end up emitting CO_2 to the atmosphere, but the carbon is used twice — rather than once — before being released. The climate benefit of the double use comes from the displacement of virgin fossil fuels that the vehicles would otherwise have used.

BUILT ENVIRONMENT. Carbon in the captured CO_2 can also be used as a component of novel construction materials that sequester the carbon in buildings, roads or other components of the built environment. This approach offers sequestration similar to geological storage, although the average duration of storage in construction materials might be lower than in the case of geological storage. Use in the built environment can encourage displacement of more emissions-intensive materials.

ACTIONS

- Continue support for research in Washington's geological storage potential for CO_2.
- Incorporate carbon capture, use and storage technologies in the portfolio of Centralized Technical Assistance.

[121] Exhaust heat can also be used for additional electric generation, in a combined cycle power plant (usually a combined cycle combustion turbine, "CCCT"). However, we are treating combined cycle power plants as an electric sector technology, not an industrial sector technology.

[122] "National Assessment of Geologic Carbon Dioxide Storage Resources - Results," U.S. Geological Survey, Circular, 2013, https://doi.org/10.3133/cir1386.

[123] B. Peter McGrail et al., "Potential for Carbon Dioxide Sequestration in Flood Basalts: SEQUESTRATION IN FLOOD BASALTS," *Journal of Geophysical Research: Solid Earth* 111, no. B12 (December 2006): n/a-n/a, https://doi.org/10.1029/2005JB004169.

2. Establish a Technology-Neutral Regulatory Framework

As an alternative to prescriptive, process-specific actions to address industrial emissions, a better approach may be to pursue one or more technology-neutral regulatory frameworks aimed squarely at the primary desired outcome of reducing greenhouse gas emissions. Two such mechanisms are a low carbon fuel standard (LCFS) to reduce the carbon intensity of fuels used in industrial and motor vehicle applications and a regulatory program to reduce emissions from stationary sources, similar to the Department of Ecology's Clean Air Rule (CAR).

A third, more comprehensive mechanism would be an economy-wide cap and trade program. Cap and trade is a proven strategy for reducing emissions in the industrial sector. It has been used in many countries around the world and in California, Quebec and to a more limited degree in the Regional Greenhouse Gas Initiative (RGGI), which includes 10 Northeast U.S. states.

2.1. Adopt a Low Carbon Fuels Standard

California, Oregon and British Columbia have all adopted relatively similar LCFS policies.[124, 125, 126, 127] An LCFS displaces conventional gasoline and diesel fuels with lower-carbon substitutes. An LCFS could help drive decarbonization across all segments of the transportation sector, as well as foster the development of clean fuels needed for important Washington industries.

Vehicle fleets and light equipment at industrial facilities consume some gasoline, while vehicle fleets, off-road equipment and backup generators use significant quantities of diesel. An LCFS could include off-road diesel, aviation fuel and/or marine fuels to expand its impact on industrial sector emissions.

> An effective LCFS would encourage clean fuels production in the state and achieve parity with similar standards in Oregon and California.

An LCFS could be structured so that revenue from credit sales fund zero emission vehicle charging and fueling infrastructure and improve the economics of in-state carbon capture and clean fuels production. Biofuels and potentially hydrogen and electrofuels could provide the state valuable flexibility in reducing transportation emissions from difficult-to-decarbonize activities such as aviation, long-distance or heavy-duty trucking and maritime shipping.

An effective LCFS would encourage clean fuels production in the state and achieve parity with similar standards in Oregon and California. In addition, an LCFS can be designed to recognize other environmental or economic benefits that result from some clean fuels. These co-benefits may include the reduction of wildfire risk when using waste biomass from forest management, the use of feedstocks that limit impacts on food crops and the use of co-products for biofuel manufacturing.[128]

ACTION

- Enact and implement an LCFS to establish a market and funding mechanism for clean fuels production.

[124] California Air Resources Board, "Low Carbon Fuel Standard," November 16, 2015, http://www.arb.ca.gov/regact/2015/lcfs2015/lcfsfinalregorder.pdf.California Air Resources Board.

[125] Chapter 754, Oregon Laws 2009, An Act, HB 2186, Relating to greenhouse gas emissions; and declaring an emergency.

[126] Consolidated Statutes of British Columbia, Chapter 16, Greenhouse Gas Reduction (Renewable and Low Carbon Fuel Requirements) Act.

[127] Julie Witcover, "Pacific Coast Collaborative Low Carbon/Clean Fuel Standard Program Comparison" (UC Davis PIEEE, June 2018).

[128] R. Divyabharathi and P. Subramanian, "Hydrothermal Liquefaction of Paddy Straw for Biocrude Production," *Materials Today: Proceedings*, March 2020, https://doi.org/10.1016/j.matpr.2020.02.390.

2.2. Regulatory Tools to Measure, Mitigate and Reduce Emissions from Industrial Sources

In 2016, the Department of Ecology adopted the CAR to address the major sources of greenhouse gases.[129] The proposed rule adopted emission standards to cap and reduce greenhouse gas emissions from significant in-state stationary sources, petroleum product producers, importers and distributors and natural gas distributors operating within Washington. Covered entities were required to reduce emissions 1.7% each year.

In March 2018, the Thurston County Superior Court ruled that parts of the CAR were invalid, preventing implementation of the rule. Compliance with the rule was suspended. On Jan. 16, 2020, the Washington State Supreme Court ruled that the portions of the rule that applied to stationary sources were valid, but that the portions that applied to indirect sources, such as natural gas distributors and fuel suppliers, were invalid. The Supreme Court sent the case back to the lower court to determine how to separate the rule.

The original CAR was based on greenhouse gas limits in place prior to 2020 (25% below 1990 levels by 2035). A new rule focused on stationary sources and designed to meet the newly adopted 2050 limit could result in a more stringent obligation than the original CAR, potentially requiring annual reductions of 3.5% per year. The Department of Ecology has not yet identified next steps for the CAR.

In a separate action and under explicit direction by the Governor, the Department of Ecology has begun rulemaking to strengthen and standardize the consideration of climate change risks, vulnerability and impacts in environmental assessments for major projects with significant environmental impacts. The rule will establish uniform methods, processes, procedures, protocols or criteria that ensure a comprehensive assessment and quantification of direct and indirect greenhouse gas emissions resulting from a project.

Port of Seattle. Clean Energy Transition Institute

ACTION

- Washington should continue to explore regulatory mechanisms to measure, mitigate and reduce greenhouse gas emissions from the operation and siting of significant in-state stationary sources, petroleum product producers, importers and distributors of natural gas.

2.3 Address Competitive Issues Raised by Emissions Policies

While there are many advantages to technology-neutral regulatory approaches, they also raise a concern about competitive effects on firms that serve markets outside the state. State-level emissions limits or fees may result in "leakage," where apparent emissions reductions in one state are offset by emissions increases in other states or countries. The industries that are most susceptible to leakage effects are referred to as energy-intensive, trade-exposed industries (EITEs). Examples of EITE industries include pulp and paper, cement, glass and metals manufacturing.

The appropriate response to concern about leakage is not necessarily to excuse EITEs from emissions reductions, but to structure state policy so leakage risk is anticipated and addressed. First, the state should anchor its industrial emissions policies in a detailed understanding of the manufacturing activity in Washington. Recent work for the Oregon Carbon Policy Office provides a good example.[130]

[129] "Clean Air Rule," Washington State Department of Ecology, n.d., https://ecology.wa.gov/Air-Climate/Climate-change/Greenhouse-gases/Reducing-greenhouse-gases/Clean-Air-Rule.

[130] "Oregon Sectoral Competitiveness under Carbon Pricing" (Vivid Economics, 2018), https://digital.osl.state.or.us/islandora/object/osl%3A676559.

Without data on energy costs, manufacturing processes and competitive conditions, the state might relax emissions reduction requirements for a firm or industry that would not actually present a leakage risk. It is possible through engineering and economic analysis to measure the actual risk of leakage for individual industries and plants. The results are likely to change over time. The state should undertake this analysis as part of an ongoing regulatory program for direct emitters.

Second, Washington should adopt industrial emissions reduction policies that are consistent with other jurisdictions. Leakage occurs when inconsistent regulations create an incentive to shift manufacturing activity to a less regulated jurisdiction. Strong inter-state partnerships or other multi-jurisdiction approaches can help avoid EITE flight, emissions leakage and job loss to other states.

Washington regularly collaborates with Oregon, California and British Columbia through the Pacific Coast Collaborative and other forums. A uniform policy framework among like-minded jurisdictions, such as was developed under the Western Climate Initiative,[131] continues to be the best approach to minimize negative economic and environmental effects among jurisdictions. Just as a geographically large energy economy creates market efficiency, a geographically large policy environment promotes least-cost solutions and accommodates niche markets, experimental policies or staged policy implementation.

Third, Washington should consider incentives for industrial efficiency improvements. Well-designed incentives would enhance the competitiveness of manufacturing firms located in the state and reduce leakage risk.

ACTIONS

- Develop and maintain data on processes, markets and costs of manufacturing activities in Washington and use this information to identify EITEs and craft responsive emissions reduction policies.
- Maintain and strengthen Washington's engagement with the Pacific Coast Collaborative, with a continued focus on advancing coordinated climate and industrial policies along the West Coast.
- Increase incentives and support for industrial efficiency, emission control and clean technology upgrades, including consideration of an industrial transformation bank, incorporating strong labor and equity standards to fund the retooling and upgrading of Washington's EITEs and low-carbon fuel pilot projects.

[131] "Program Design and Implementation," Western Climate Initiative, accessed November 1, 2020, https://wci-inc.org/our-work/program-design-and-implementation.

Logging truck on Snow Creek Road, Quilcene, WA.
Clean Energy Transition Institute

3. Develop and Implement a Coordinated Clean Energy Industrial Policy

Emissions from the industrial sector add a complex layer to an already challenging task for policy makers as they seek to promote economic vitality, business development and high-quality jobs. Climate policy must be incorporated into a coherent industrial policy. This approach has proven successful in countries around the world.[132, 133, 134] With an electric grid considerably cleaner than most states in the U.S., technological expertise, manufacturing history, fuel-refining infrastructure and biomass resources, Washington has an opportunity to become a world leader in the clean energy economy, while at the same time reducing the environmental impacts of existing industries in the state.

Washington possesses significant advantages to attract the manufacturing supply chains of solar, storage and microelectronic technologies that will be key to driving our low carbon economy, particularly as it relates to polysilicon-based technologies.

3.1. Adopt a Comprehensive Clean Energy Plan for Industrial Policy

Industrial policy is a matched set of tools and policies: procurement, workforce development, infrastructure development, tax incentives and research and development. Comprehensive industrial policy for climate and energy goals requires coordinated alignment and aggregation of interventions across different levels of government and between the public and private sectors, leveraging the strengths of agencies, jurisdictions and sectors.

Each country, state, or region's industrial policy generally emerges organically from existing industry clusters that are the natural fit for the jurisdiction's resources, culture and history. New industrial opportunities build on underlying competitive advantages in a region and these competitive advantages may change over time. Thus, an industrial ecosystem is not static and designing a low-carbon future for industry will take patience, focus and coordinated policy.

In some cases, the development of industries has created sacrifice zones, geographic areas that have been permanently impaired by environmental damage or economic disinvestment, often through locally unwanted or unusable land. It is important that Washington's policies ensure that rapid decarbonization does not come at the risk of creating sacrifice zones. In developing a clean energy industrial policy, business leaders, community representatives and labor unions must be engaged from the outset in mapping the priorities of those impacted. The policy must promote labor standards and shared benefits.

The state should lead with an equitable governance policy approach among key constituents to design a process to achieve decarbonization goals expeditiously and maximize benefits while minimizing risks for people who live or work where a project or manufacturing hub may be located and decreasing the likelihood that industries and jobs will leave Washington for other states.

ACTION

- Develop a coordinated clean energy industrial policy framework that supports the ability of industry to help decarbonize the buildings, transportation and electricity sectors and catalyzes regional decarbonization.

3.2 Create a Structure to Implement a Clean Industrial Policy

The success of the Washington 2021 State Energy Strategy and especially its industrial sector provisions, will depend on continued and coordinated participation across state agencies. Strengthened state agency leadership could feature more frequent energy planning, increased data gathering authority or increased regulatory authority.

States in the U.S., including Washington, have not typically engaged in frequent energy planning, increased data gathering and increased regulatory authority to steward industrial policy. Getting serious about industrial policy means making a clear home for it, within the state's current

[132] "Investment and New Industrial Policies: World Investment Report 2018" (UNCTAD, Division of Investment, 2018).

[133] Michael Landesmann and Roman Stollinger, "The European Union's Industrial Policy: What Are the Main Challenges?" (The Vienna Institute for International Economic Studies, January 2020).

[134] Todd Tucker, "Industrial Policy and Planning: What It Is and How to Do It Better" (Roosevelt Institute, July 2019), https://rooseveltinstitute.org/wp-content/uploads/2020/07/RI_Industrial-Policy-and-Planning-201707.pdf.

organization of agencies. The Office of Economic Development and Competitiveness (OEDC) within Department of Commerce is the obvious location in which to place industrial policy stewardship.

Greater attention to industrial energy planning would improve the state's influence over the pathways Washington takes to achieving its greenhouse gas reduction limits and industrial policy targets. The current process with many years between energy planning exercises means either that each plan eventually becomes perceived as old and therefore ignored; or, if each strategy is taken seriously, that Washington locks itself into approaches or policies that may no longer be the best choice in the context of changing technologies, politics, or economics as the decade goes by. More frequent planning would enable a nimbler approach to the state's energy policy in the industrial sector.

An important benefit of developing a more climate-aware industrial policy is that it could lead to better processes for siting industrial facilities, perhaps using a dedicated, multi-agency entity similar to the Energy Facility Site Evaluation Council (EFSEC).

ACTIONS

- The Legislature should establish responsibility for clean energy industrial policy within state government, with robust data collection and regular planning for the industrial sector.
- As part of its industrial policy, the Legislature should consider a review of potential tools to streamline permitting and siting of clean industrial activities that protect communities from disproportionate impacts.

> Greater attention to industrial energy planning is required to improve the state's ability to achieve its greenhouse gas reduction limits.

3.3 Provide Centralized Technical Assistance

The most effective policy framework for decarbonization will be one that includes both a downward pressure on emissions and an upward lift for the technologies that can achieve it. Knowledge about efficiency, electrification, process emissions reduction and carbon capture and storage needs to be broadened so that a wide spectrum of industrial entities have access. Since Washington contains a few entities within each given major industrial subsector, partnering regionally with multiple states to provide centralized technical assistance could be an effective approach.

A few existing programs can serve as examples. Washington's Department of Ecology has a program offering efficiency services to manufacturing and industrial facilities, the primary directives of which are efficiency, waste reduction and reducing regulatory overhead for small- and medium-sized plants. The Washington State University (WSU) Energy Program's industrial services group helps manufacturers adopt efficient technologies, productivity improvements and best practices by integrating and customizing products and services and provides technical assistance, assessments, training and project planning.

The New York State Energy Research & Development Authority manages five industrial programs that combine a focus on efficiency with energy management to increase competitive advantages and resiliency. Three that align particularly well with Washington's industrial energy policy offer strategic energy management, flexible technical assistance and on-site energy manager services.[135] Wisconsin's Focus on Energy program also offers support to industrial buildings through energy and local advisors on energy-saving equipment, technology and renewable energy options to reduce energy consumption and lower energy bills.[136]

ACTION

- Expand the Department of Ecology's *Efficiency Services for Manufacturing and Industrial Facilities* program and the WSU Energy Program's Industrial Efficiency team, incorporating best practices from other jurisdictions.

[135] "NYSERDA Industrial Programs," New York State, n.d., https://www.nyserda.ny.gov/All-Programs/Programs/Industrial-Programs.
[136] "Wisconsin's Focus on Energy," Focus on Energy: Partnering with Wisconsin Utilities, n.d., https://focusonenergy.com/.

4. Support Clean Energy Research, Innovation and Deployment

As Washington embraces the clean energy transition, leaders can build on the state's foundations in aerospace, maritime, information and communications technology (particularly data center infrastructure, artificial intelligence and machine learning), grid modernization and decarbonizing buildings. Support can be enlisted from Washington's world-class manufacturers, technologists and academic research organizations, including those in regional comprehensive universities across the state.

State policies can catalyze activities that align with sustainability, climate and carbon investment funds being established and policies being adopted by the private sector, including Microsoft, Amazon and other sector leaders. All this will help the state to more readily develop the technology and innovation required to meet the state, national and global climate goals, offer opportunities for economic and job growth and strengthen technology supply chains. Collectively, these efforts can help ensure our existing and future industries have access to the tools needed to reduce the carbon intensity of their operations.

As the state advances towards a net-zero emissions future, gas and liquid fuels are expected to continue to be part of the energy mix for some time to come — both as a limited source for electricity generation and for use in specific transportation, building and industrial applications. There is a need to develop and deploy technologies that can economically provide decarbonized fuels.

New technologies being researched, developed and deployed include "green hydrogen"[137] from electrolysis powered by renewable or non-emitting electricity; carbon capture, use and storage which can "decarbonize" conventional fossil fuels used for heat or electricity; and synthetic fuels produced by combining hydrogen and non-fossil sources of carbon. These technologies offer the potential to contribute to a decarbonized future, but require continued investment in research and development, pilot programs and commercialization, as well as a favorable regulatory environment and government financial support to reduce the significant risks associated with bringing new technologies to market.

Dr. Lisa Brown touring the Clean Energy Institute, October 2019. Department of Commerce

As discussed in Chapter C-Use Energy More Efficiently and Decarbonize Transportation Energy, even under the aggressive Electrification Scenario, a large number of internal combustion engines will remain on the road in 2030. This means there will be an immediate need to produce low-carbon liquid fuels to replace fossil fuels. The industrial sector and especially Washington's robust petroleum refining industry, could play an important role in meeting the demand for those fuels during the next decade and beyond.

Petroleum fuels are hydrocarbons, molecules built primarily from carbon and hydrogen and the technologies available to synthesize petroleum substitutes are well known. The petroleum industry in Washington has the equipment and the know-how to become a leading innovator and producer of synthetic fuels.[138, 139] Washington's 2030 target is an excellent catalyst for the local refineries to become world leaders in low-carbon fuel manufacture. While the technologies to synthesize hydrocarbons are well known, the sources of the carbon and hydrogen atoms used to do so could be defining elements of Washington's clean energy paradigm.

[137] "Hydrogen," BP, n.d., https://www.bp.com/en/global/corporate/energy-economics/energy-outlook/demand-by-fuel/hydrogen.html.

[138] A.A. Lappas, S. Bezergianni, and I.A. Vasalos, "Production of Biofuels via Co-Processing in Conventional Refining Processes," Catalysis Today 145, no. 1–2 (July 15, 2009): 55–62, https://doi.org/10.1016/j.cattod.2008.07.001.

[139] Susan van Dyk et al., "Potential Synergies of Drop in Biofuel Production with Further Co processing at Oil Refineries," Biofuels, Bioproducts and Biorefining 13, no. 3 (May 2019): 760–75, https://doi.org/10.1002/bbb.1974.

Maritime Blue foil ferry. Department of Commerce

4.1. Continue to Invest in the Clean Energy Fund

Washington's Clean Energy Fund (CEF) was conceived in 2013 to support "projects that provide a benefit to the public through development, demonstration and deployment of clean energy technologies that save energy and reduce energy costs, reduce harmful air emissions or otherwise increase energy independence for the state."[140] The CEF has received appropriations through a series of biennial budgets up to and including appropriations in the 2019 capital budget.

To date, through awards of $118 million, Washington's CEF investments have successfully leveraged over $400 million to support innovative projects including grid modernization and storage; energy efficiency and renewable energy projects (wind, solar, bioenergy) on farms and in commercial buildings and homes; and deployment of electrification charging infrastructure. The funding has resulted in energy savings, emission reductions and job creation throughout the energy supply chain, positioning the state as a leader in clean technology development.

In the immediate future, policy makers' investments in the CEF represent a proven opportunity for economic development and position Washington to leverage federal clean energy dollars. In the long term, the CEF has a structure that can help support the innovation and infrastructure adaptation necessary to make our state's clean energy transition. With its strategic goal of "developing, demonstrating and deploying clean energy technologies that save energy and reduce energy costs, reduce harmful air emissions, or otherwise increase energy independence for the state," the CEF can continue to be a tool to build on Washington's clean energy policies and sectoral strengths, ensure costs and benefits are equitably distributed and help the state rebuild our economy.

ACTION

The Legislature and the Department of Commerce should continue to support the CEF and deploy the resources consistent with the recommendations of the Energy and Climate Policy Advisory Committee in the Report to the Legislature submitted in Dec. 2020.[141]

4.2. Cluster around Centers of Research, Development and Entrepreneurship

Washington is renowned for its technical innovation, particularly in the aerospace and information industries. The state is home to the Pacific Northwest National Laboratory, one of 17 national energy laboratories. The Clean Tech Alliance represents over 1,100 members facilitating the growth of clean technology companies and jobs through education, research and services. Washington's large and regional research universities also are a ready source of innovation to support an industrial policy based on clean energy.

Washington's Maritime Blue Strategy was created in 2019 to accelerate innovation and create the nation's most sustainable maritime industry by 2050.

The Maritime Blue strategy is focused on shifting towards a thriving, low-carbon industry; becoming a global innovation hub; leading the nation in efficient, clean and safe working waterfronts; supporting a 21st century workforce; and establishing a world-class maritime cluster.[142]

[140] Section 1074(1), Engrossed Substitute Senate Bill 5035, 2013. https://app.leg.wa.gov/billsummary?BillNumber=5035&Year=2013&Initiative=false

[141] "Energy and Climate Policy Advisory Committee," Washington State Department of Commerce, accessed November 1, 2020, http://www.commerce.wa.gov/growing-the-economy/energy/energy-and-climate-policy-advisory-committee/.

[142] "Washington Maritime Blue Launches Ambitious Plan for Economic Growth, Jobs, Ocean Health," January 8, 2019, https://www.commerce.wa.gov/news-releases/growing-the-economy/washington-maritime-blue-launches-ambitious-plan-for-economic-growth-jobs-ocean-health/.

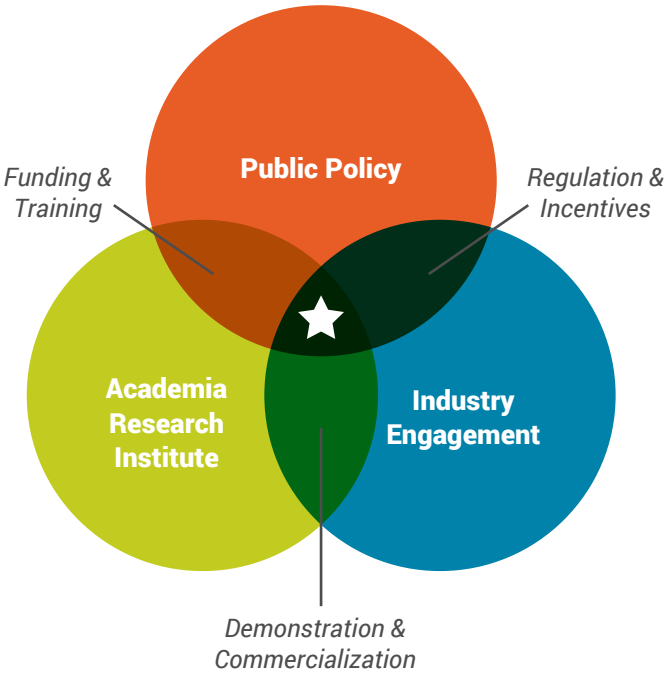
As a "cluster organization,"[143] Maritime Blue gathers businesses, public entities, community organizations, researchers and training institutions together to build a low-carbon marine industry that remains economically competitive. To date, Maritime Blue has assembled 55 industry members along with four research institutions, 14 organizational partners and 22 public sector partners and leveraged $6.5 million in public funding for programming and projects and $250,000 in private sponsorships.

It has garnered $32 million in private capital and $6 million in business sales related to the first cohort of 11 start-ups. This innovative project has successfully demonstrated a public-private partnership to develop economic advances for decarbonization of an industry. The example could serve as a framework from which to decarbonize the state's other industries.

In addition to nurturing industry clusters, there are opportunities for the state government to partner with individual companies. This can result in carbon reduction to help the state achieve its greenhouse gas emission limits, but also creates a forum for the state to learn from private sector initiatives.

Microsoft, for example, has established an investment fund supported by the company's internal carbon tax to provide funding for early stage clean energy technologies.[144] Alaska Airlines plans to reduce carbon emissions with flights powered by sustainable aviation fuel in key routes.[145] Skanska, a construction firm, pledged to eliminate emissions from both direct operations and its supply chain.[146] Amazon has pledged to be zero net carbon by 2040 and announced an initiative to electrify its delivery fleet.[147] PACCAR, a manufacturer of trucks, has invested in improving energy efficiency and reducing emissions, water consumption and waste at its manufacturing facilities, in combination with disclosing its greenhouse gas emissions.[148]

THE COMPONENTS OF A CLUSTER



THE ROLE OF A CLUSTER

Communication & marketing
Funding & investment
Knowledge & innovation collaboration
Incubation and commercialization
Joint industry projects (JIP)
Cross-cluster collaboration
Strategy review

[143] "World Class Cluster," Washington Maritime Blue, n.d., http://maritimeblue.org/cluster-2/.

[144] David Roberts, "Microsoft's Astonishing Climate Change Goals, Explained," *Vox*, 2020, http://www.voxx.com/energy-and-environment/2020/7/30/21336777/microsoft-climate-change-goals-negative-emissions-technologies?mbid=&bxid=5ec7510be36b.

[145] "Alaska Airlines and Microsoft Sign Partnership to Reduce Carbon Emissions with Flights Powered by Sustainable Aviation Fuel in Key Routes," *Microsoft News Center* (blog), October 22, 2020, https://news.microsoft.com/2020/10/22/alaska-airlines-and-microsoft-sign-partnership-to-reduce-carbon-emissions-with-flights-powered-by-sustainable-aviation-fuel-in-key-routes/.

[146] "Skanska UK Pledges Zero Emissions by 2045, Leads Construction Industry in Climate Commitments," *Mighty Earth*, May 19, 2019, https://www.mightyearth.org/skanska-uk-pledges-zero-emissions-by-2045-leads-construction-industry-in-climate-commitments/.

[147] Mary Meisenzahl, "Amazon Just Revealed Its First Electric Delivery van of a Planned 100,000-Strong EV Fleet — See How It Was Designed," *Business Insider*, October 8, 2020, https://www.businessinsider.com/amazon-creating-fleet-of-electric-delivery-vehicles-rivian-2020-2.

[148] "Paccar: Sustainability," n.d., https://www.paccar.com/about-us/environmental-and-social/environmental/.

ACTIONS

- Replicate Maritime Blue for other centers of research and development to accelerate and support emerging low-carbon industrial opportunities.
- Create a knowledge center on public-private collaboration to help firms make and meet broader climate commitments through capacity building and knowledge sharing.
- Expand programs to incentivize research and market development for commercial low-carbon fuels; heat pumps; embodied carbon materials; direct air capture (DAC); carbon capture, utilization and storage (CCUS); electrification technologies; grid modernization; artificial intelligence and machine learning; and circular economy processes.

4.3. Continue Washington's Leadership in Sustainable Aviation

The ports of Seattle, Spokane and Portland, along with The Boeing Company, Alaska Airlines and Climate Solutions were early out of the gate in creating the Sustainable Aviation Fuels Northwest (SAFN) initiative,[149] the first regional assessment of feedstock pathways for producing sustainable jet fuel in the U.S.

SAFN led to two large USDA-funded advanced biofuels research consortia in Washington, Advanced Biofuels Northwest (University of Washington) and the Northwest Advanced Renewables Alliance (Washington State University), both of which dealt extensively with feedstock and conversion supply chain analysis. Until 2018, the Legislature funded the Sustainable Aviation Biofuels Workgroup,[150] which facilitated conversation among government, the aviation industry, research institutions and biomass feedstock producers to advance sustainable aviation biofuels in Washington.

Today, WSU co-leads the Center of Excellence for Alternative Jet Fuels (ASCENT)[151] with the Massachusetts Institute of Technology to create science-based solutions for the aviation industry's most difficult environmental challenges. ASCENT released a February 2020 study[152] looking at the availability of sustainable biomass in the region.

ACTIONS

- Explore the viability of creating an electric aviation cluster to implement Washington's Green Economy report[153] recommendations to leverage the expertise of the University of Washington's Clean Energy Institute (CEI) to persuade international electric aircraft manufacturers to develop electric aircraft in Washington.
- Create a business environment where Washington is seen as a center of excellence for electric aviation.
- Support building a testing facility in Washington for electric aircraft.
- Invest in upgraded infrastructure for testing electric aircraft.
- Continue to support the efforts of ASCENT and the Sustainable Aviation Biofuels Work Group to coordinate research, development and deployment of low-carbon liquid aviation fuels.

> Washington should build on its successful partnerships working towards decarbonization of the aviation and maritime industries.

[149] "Sustainable Aviation Fuels Northwest," Climate Solutions: Accelerating the Transition to our Clean Energy Future, n.d., https://www.climatesolutions.org/sustainable-aviation-fuels-northwest.

[150] "Sustainable Aviation Biofuels Workgroup" (Washington State Legislature, January 26, 2018), https://apps.leg.wa.gov/ReportsToTheLegislature/Home/GetPDF?fileName=Sustainable%20Aviation%20Biofuels%202017%20Update%20Final_435d458c-b62c-4bdd-868d-8f9e4f0576b5.pdf.

[151] "Ascent - The Aviation Sustainability Center," Ascent, n.d., https://ascent.aero/.

[152] Port of Seattle and Washington State University, "Potential Northwest Regional Feedstock and Production of Sustainable Aviation Fuel," 2020, https://www.portseattle.org/sites/default/files/2020-07/PofSeattleWSU2019_final.pdf.

[153] "Washington's Green Economy" (Washington State Department of Commerce, 2020), https://deptofcommerce.app.box.com/s/jpy44m0svj05sfxp8353khsceq42lfss.

4.4. Explore a New Hydrogen Economy

Twenty years ago, a vision for the "hydrogen economy" took hold, in which a nontoxic, odorless, gaseous fuel speeds fuel-cell-powered "hypercars."[154] While development has occurred more slowly than expected, hydrogen can potentially play an important role in reducing greenhouse gas emissions from the industrial sector.

Hydrogen is not an energy source but an energy carrier. Hydrogen requires energy to produce and like electricity, it is only as clean as the feedstock used to produce it. Hydrogen is useful as a directly consumed power source for fuel cells and it can be used for hydrocarbon synthesis to produce the liquid fuels to achieve the state's 2030 greenhouse gas reduction limits. Hydrogen can also be used to promote the manufacture of more novel liquid energy carriers, such as ammonia or hydrazine.

Green hydrogen production is an important manufacturing opportunity for Washington industry. Petroleum refineries already include systems to produce and handle hydrogen, so are likely starting points for increasing production. Washington can learn from the European Union's hydrogen strategy, which calls for building up a hydrogen industry that can enable large-scale use of renewable and low-carbon hydrogen as a replacement for fossil fuels in industry and hard-to-decarbonize sectors, an energy carrier and form of energy storage and a feedstock for synthetic liquid fuels.[155]

ACTION

- Commerce should work with utilities, industrial firms, federal agencies and other stakeholders to accelerate the development of hydrogen production and should encourage pilot projects and research activities.

4.5. Continue to Assess Biogenic Feedstocks as a Foundational Resource

Fossil fuels are the result of geologic sequestration of ancient vegetation. Plants growing today also contain carbon and hydrogen. Whether the state's liquid and gaseous fuels are derived from fossil sources, dedicated crops, organic waste streams or other biogenic sources, or are synthetic fuels produced from any number of non-fossil sources of carbon and hydrogen, they result in the same two combustion products: carbon dioxide and water.

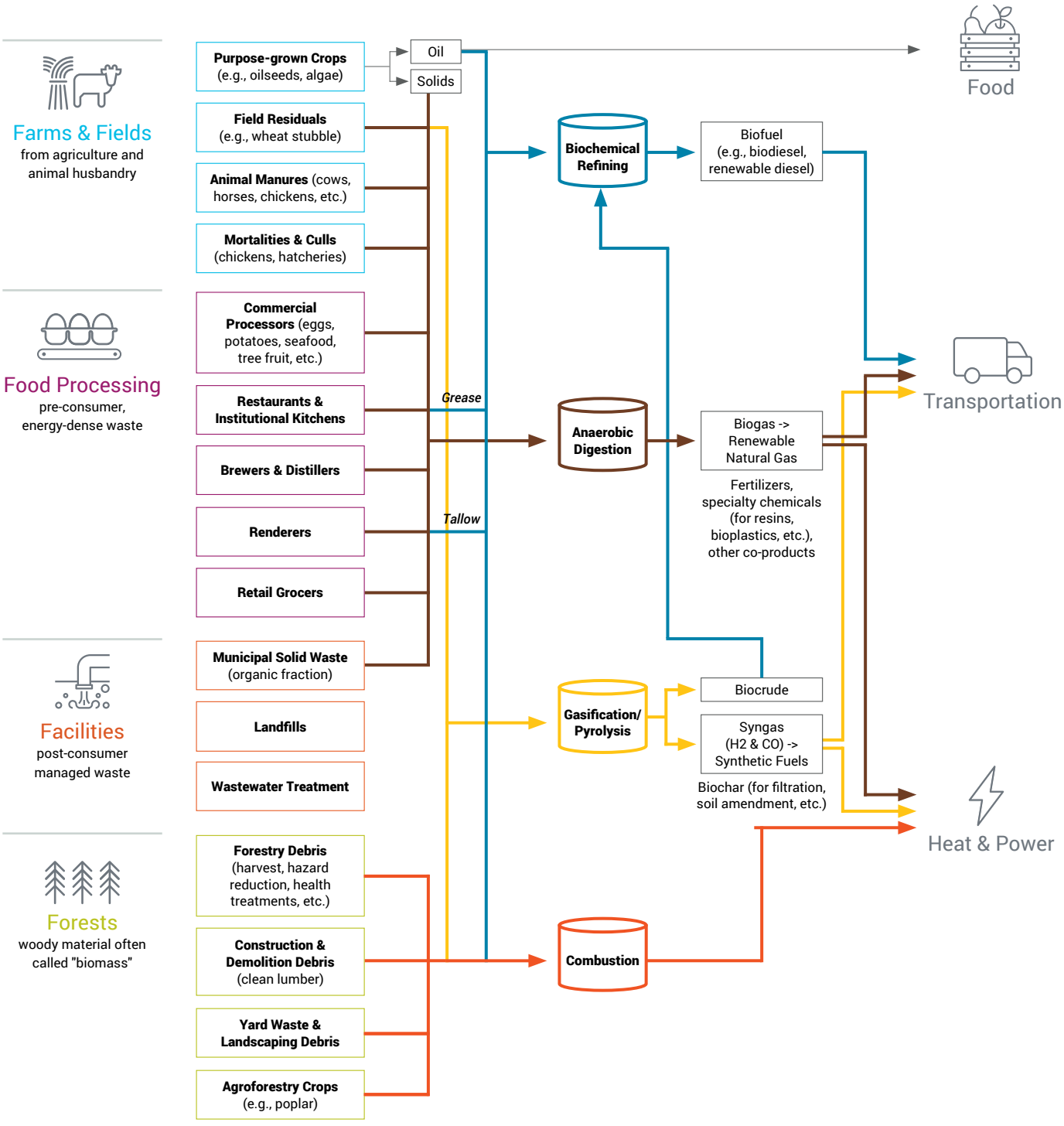
[154] Amory B. Lovins and David R. Cramer, "Hypercars, Hydrogen and the Automotive Transition," *International Journal of Vehicle Design* 35, no. 1/2 (2004): 50, https://doi.org/10.1504/IJVD.2004.004364.

[155] European Commission, "A Hydrogen Strategy for a Climate-Neutral Europe," 2020, https://ec.europa.eu/energy/sites/ener/files/hydrogen_strategy.pdf.

Hydrogen-powered passenger vehicle. audioundwerbung/iStock

FIGURE 23. PRIMARY BIOENERGY PATHWAYS IN WASHINGTON STATE

This diagram represents the feedstocks and process technologies discussed throughout the strategy that are best suited to deliver various forms of bioenergy and value-added co-products in Washington.



Biogas plant with cows.

The difference is what happens *after* the feedstocks have been extracted. As feedstocks derived from the management and harvest of agricultural and forestry crops are used for biofuel production, new crops are grown on agricultural and forest lands, extracting carbon dioxide from the atmosphere effectively compensating for what is being emitted through combustion of the biofuel.

Whether in gaseous, liquid or solid form, biogenic fuels can support those industrial processes most in need of heat or most in need of liquid or gaseous fuels, supplementing the role of electricity in meeting thermal needs. The use of biogenic feedstocks for heat, electricity and liquid and gaseous biofuels is inherently more complex than other forms of renewable energy production. Biogenic feedstocks offer opportunities for economic development, waste utilization and value-added co-products absent in other forms of renewable energy generation. Some feedstocks, however, raise concerns about sustainable sourcing, scale and siting.

ACTION

- The departments of Natural Resources, Agriculture, Ecology and Commerce, along with WSU's Center for Sustaining Agriculture and Natural Resources, should expand collaborative efforts to assess Washington's biogenic feedstocks to help inform future state policies. With specific focus of on developing markets for low-grade woody biomass from forest management and fire hazard reduction processes, including opportunities for various methods of carbon sequestration as informed by DNR's Carbon Sequestration Advisory Group.[156]

> Using biogenic feedstocks for heat, electricity and liquid and gaseous biofuels is complex.

[156] "Carbon Sequestration Advisory Group," Washington State Department of Natural Resources, accessed December 1, 2020, https://www.dnr.wa.gov/CarbonAdvisoryCmte.

5. Expand Policies to Consider Consumption-based Emissions

Emissions associated with the manufacture and transport of consumer products are referred to as "upstream emissions," "embodied emissions" or "embodied carbon." Washington has some of the most sophisticated low-carbon manufacturing technology capabilities in the world. The state is home to some of the best-in-class facilities on the planet in terms of production of low-carbon building and manufacturing materials such as steel rebar[157] and aerospace aluminum products.[158, 159]

Global demand for low-embodied carbon materials will grow as more jurisdictions seek to reduce consumption-based emissions. Washington can continue to lead in low-carbon intensity manufacturing, contributing significantly to in-state and global reductions in greenhouse gas emissions. In addition to decarbonizing existing industry, Washington is emerging as a leader in the global clean tech industry[160] and green building,[161] presenting entirely new opportunities for high-wage jobs and economic growth.

Reducing consumption-based emissions is not an alternative to reducing production-based emissions. They are both essential strategies. Washington's Center for Sustainable Infrastructure[162] and the University of Washington Carbon Leadership Forum[163] are laying important groundwork in this area by developing standardized approaches for measuring embodied carbon.

5.1. Conduct a Consumption-based Inventory

To lower consumption-based emissions, it is important to understand Washington's consumption patterns and the extent to which consumption emissions differ from production emissions. Emission inventories that include the embodied carbon of goods and services purchased by consumers are called "consumption-basis" inventories.[164]

King County computed and reported consumption-basis inventories in 2008 and 2015. In 2015, King County's conventional community inventory reported 20 million tCO_2e, while the consumption-basis inventory reported 58 million tCO_2e, well over 2½ times higher.[165]

The state of Oregon has computed consumption-basis emissions for 2005, 2010 and 2015. In 2015, Oregon's conventional inventory reported 63 million tCO_2e, while the consumption-based inventory reported 89 million tCO_2e. The difference in Oregon's case is less dramatic than in King County because the larger geography means that more industrial sources are captured in the conventional inventory. Even so, Oregon's consumption-basis inventory is still some 41% greater than its conventional inventory.[166]

> Global demand for low-embodied carbon materials will grow as more jurisdictions seek to reduce consumption-based emissions.

[157] According to the EC3 calculator, Nucor in Seattle produces the lowest embodied carbon steel concrete reinforcing and merchant bar in the world, and Farwest Steel Corporation with facilities in Oregon and Washington, as well as CT Sales, Inc. in Woodinville and Addison Construction Supply in Tacoma are also some of the lowest carbon producers in the world for fabricated reinforcing bar (https://www.buildingtransparency.org/en/).

[158] Helen Sanders, "Carbon Counting: A Driver for U.S. Sourced Aluminum? (Part 2)," Insights and Inspirations, September 6, 2019, https://www.usglassmag.com/insights/2019/09/carbon-counting-a-driver-for-u-s-sourced-aluminum-part-2/.

[159] Kaiser Aluminum, External Affairs and United Steelworkers Local 338. Best in Class: Flat Rolled Products. Based on data from Ecometrica, http://emissionfactors.com, August 2011.

[160] Washington is home to the Clean Tech Alliance, the largest state trade association of clean tech businesses in the U.S.

[161] Paul Roberts, "Growing the Green Economy in Washington State: Exploring an Eco-Nomic Center" (CQC AWC Center for Quality Communities, March 2019), http://cfqc.org/wp-content/uploads/2019/04/ExploreEcoNomincCenterSummary.pdf.

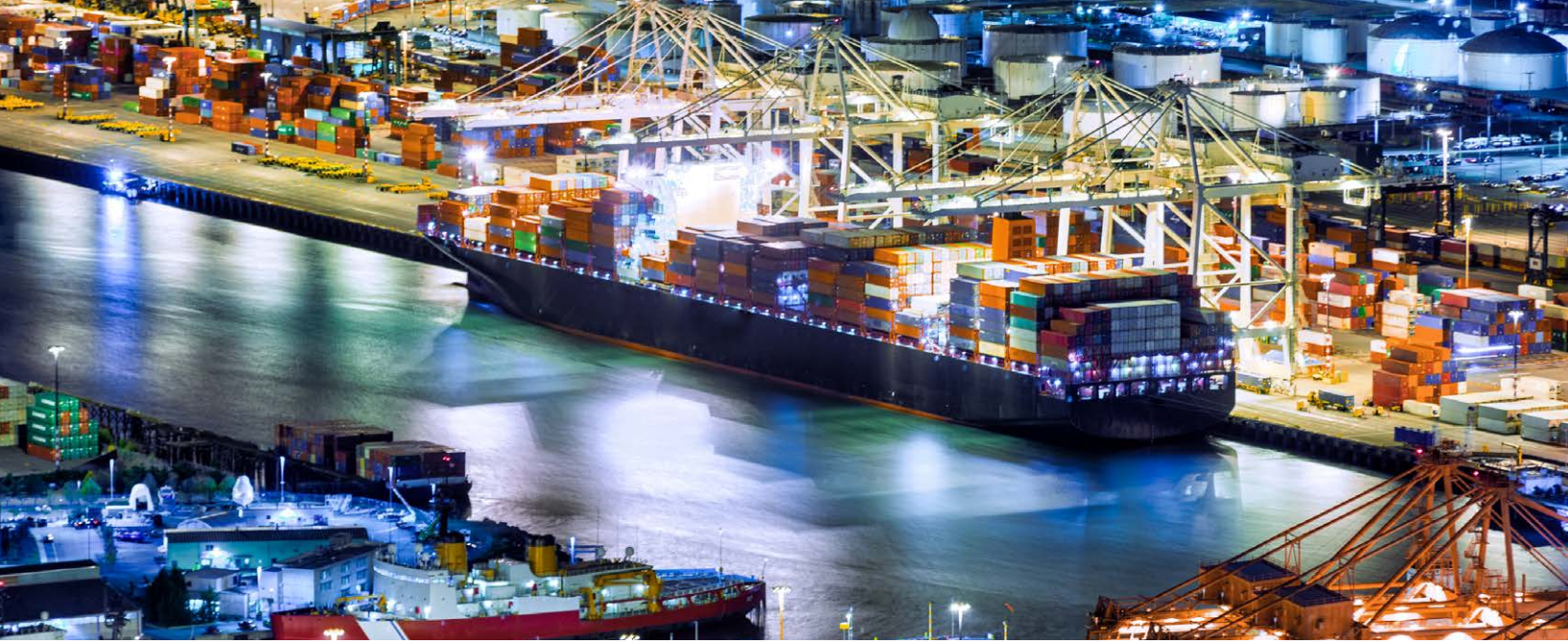
[162] "Center for Sustainable Infrastructure," accessed December 1, 2020, https://www.sustaininfrastructure.org/.

[163] "EC3 Tool Methodology," Carbon Leadership Forum, accessed October 26, 2020, https://carbonleadershipforum.org/projects/ec3-methodology/.

[164] Washington State's existing GHG inventory already treats electricity on a consumption basis, counting out-of-state emissions associated with imported electricity and discounting in-state emissions associated with exported electricity. However, doing this for all services and products is a much bigger step – electricity is just one of hundreds of product categories that would be estimated in a full, consumption-basis inventory.

[165] "King County Greenhouse Gas Emissions Inventory: A 2015 Update" (Cascadia Consulting Group, Hammerschlag & Co. LLC, December 2017), https://your.kingcounty.gov/dnrp/climate/documents/2015-KC-GHG-inventory.pdf.

[166] "Consumption-Based Greenhouse Gas Emissions Inventory for Oregon," accessed October 26, 2020, https://www.oregon.gov/deq/mm/pages/consumption-based-ghg.aspx.



Aerial view of a cargo ship loaded at a Port of Seattle container terminal. Ultima_Gaina/iStock

While the Oregon and King County inventories disclosed consumption emissions greater than production emissions, states that export more manufactured products than they import could have lower consumption-based emissions than their production-based emissions. For example, the emissions associated with Washington's aviation manufacturing industry would not be attributed to Washington in a consumption-based approach. Understanding the difference and managing reductions of both is necessary to reduce the global pool of greenhouse gas emissions rather than just shifting where those emissions occur or are measured.

Understanding consumption-based emissions is also important for equity. A household's carbon footprint generally increases with income, ranging from 19.3 to 91.5 tons of CO_2-equivalent annually. The average carbon footprint of the wealthiest households is over five times that of the poorest.[167]

ACTION

- Conduct an inventory of the embodied carbon of goods and services purchased by Washingtonians.

5.2. Incentivize Environmental Product Declarations for Products & Materials Consumed in State

Environmental Product Declarations (EPDs) often described as "nutrition labels" for carbon content, make it easy to track embodied carbon and recognize low-carbon producers. By establishing demand for and a willingness to purchase low-carbon products, private sector investments and innovation are encouraged.

EPDs are independently verified and registered documents that communicate transparent and comparable information about the life-cycle environmental impact of products.[168] Without regulatory requirements, the disclosure of life-cycle emissions is left to voluntary private sector action. While some private companies are requiring EPDs for their construction projects, state and local governments procure and fund many of these products and materials. Public agencies could play a significant role in incentivizing better disclosure practices.

ACTION

- State agencies, through the State Efficiency and Environmental Performance Office, should explore the potential for EPDs to support environmentally aware procurement policies and establish a baseline for standardized accounting and reporting.

[167] Morteza Taiebat and Ming Xu, "5 Charts Show How Your Household Drives up Global Greenhouse Gas Emissions," PBS, September 21, 2019, https://www.pbs.org/newshour/science/5-charts-show-how-your-household-drives-up-global-greenhouse-gas-emissions.

[168] The International EPD® System, "What Is an EPD? - The International EPD® System," accessed December 28, 2018, https://www.environdec.com/What-is-an-EPD/.

6. Leverage the Economic Transition to Create New Inclusive, Living-Wage Jobs

As Washington transitions to a decarbonized economy, there is an opportunity to support the recovery and competitiveness of the Washington economy and create inclusive, living-wage jobs in a wide range of areas from agriculture and manufacturing, to utilities and construction (Figure 23).[169]

These occupations tend to have higher, more equitable wages and lower educational requirements when compared with other occupations, nationally.[170] Clean energy jobs have the added indirect effect of creating health and climate benefits for Washington communities. The Low Carbon Prosperity Institute estimates that every million dollars invested in clean energy programs leads to $2.4 million in clean air and climate benefits.[171]

Workforce development must be a priority as the state emerges from the current economic recession, which has been especially hard on clean energy jobs. Prior to the economic downturn caused by the COVID-19 pandemic, Washington had a total of 83,728 clean energy jobs. Since the pandemic, the state has lost roughly 20% of its clean energy jobs.[172] Not only have these job losses upended the financial security of affected Washington households, they also threaten to deplete the workforce necessary for the clean energy transition.

Washington has experience rebuilding its clean energy workforce in the wake of a recession. In the 2008 financial crisis, the state lost tens of thousands of clean energy jobs. Using American Recovery Reinvestment Act of 2009 (ARRA) funding, the state invested in its workforce, equipping employees with the skills necessary to participate in the clean energy economy. Washington's Weatherization Assistance Program deployed $60 million of ARRA funding to hire hundreds of workers to weatherize 7,000 low-income homes, creating jobs while reducing utility bills and improving thermal comfort.[173]

E2 CLEAN JOBS WASHINGTON 2019 FINDINGS

11x more clean energy jobs in Washington than fossil fuel jobs

10.1% of Washington clean energy workers are veterans, nearly double the national average

8.3k rural Washington residents work in clean energy

7 OUT OF 10 clean energy employees in Washington work at companies with fewer than 20 employees

45% of Washington's clean energy workforce is located outside the Seattle metro area

5 OUT OF 10 counties by clean energy jobs per capita have populations fewer than 100,000—including No.1 Jefferson County which is home to 23 clean energy jobs for every 1,000 employable residents

[169] "Clean Jobs Washington 2019" (E2), accessed December 2, 2020, https://www.e2.org/wp-content/uploads/2019/12/E2-Clean-Jobs-Washington-2019.pdf.

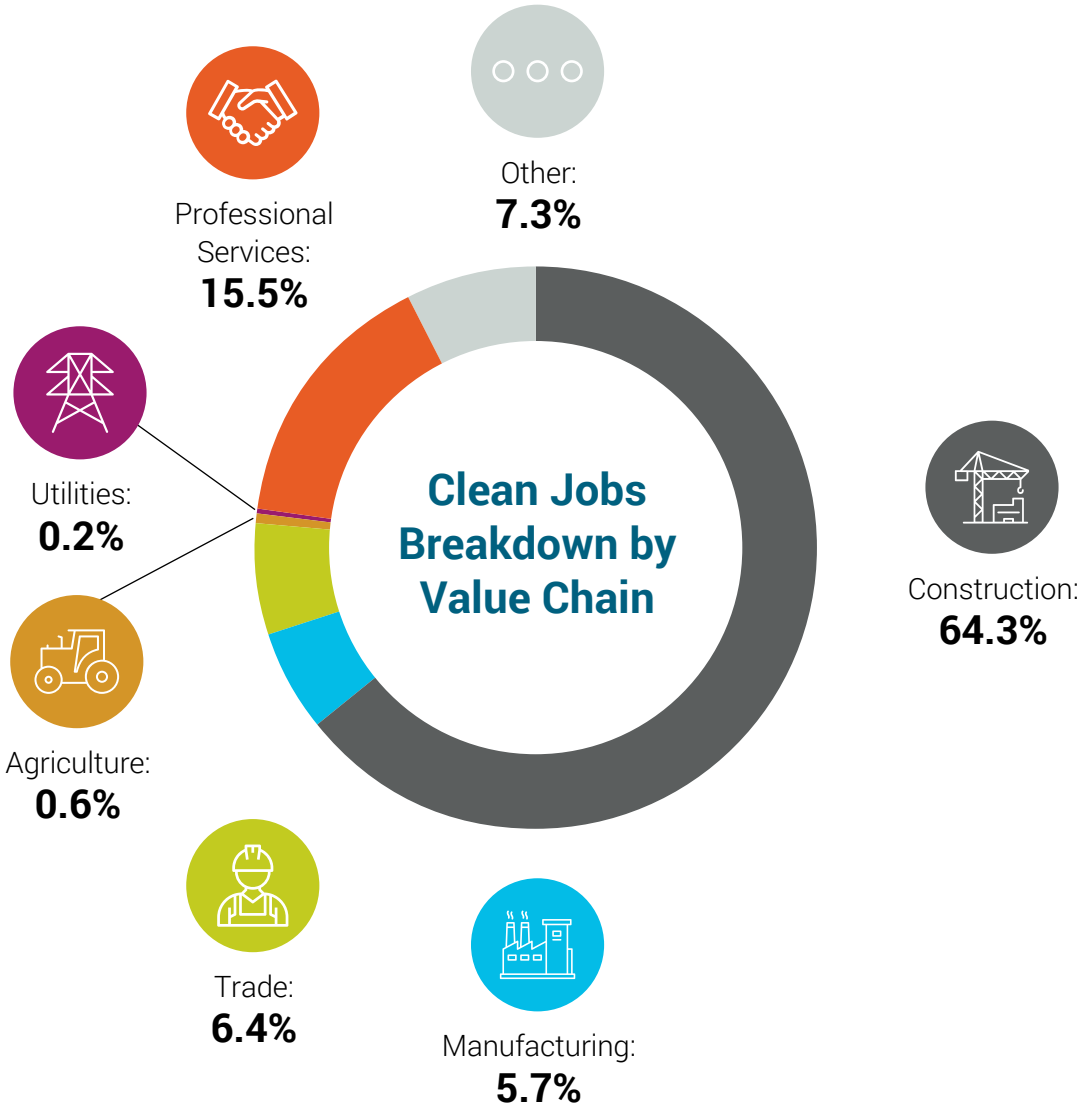
[170] Mark Muro et al., "Advancing Inclusion through Clean Energy Jobs" (Brookings, April 2019), https://www.brookings.edu/wp-content/uploads/2019/04/2019.04_metro_Clean-Energy-Jobs_Report_Muro-Tomer-Shivaran-Kane.pdf#page=18.

[171] Jonah Kurman-Faber, Kevin Tempest, and Ruby Wincele, "Building Back Better: Investing in a Resilient Recovery for Washington State" (Low Carbon Prosperity Institute, Climate Xchange, 2020), https://www.lowcarbonprosperity.org/wp-content/uploads/2020/06/Building-Back-Better-Investing-in-a-Resilient-Recovery-for-Washington-State-Website.pdf.

[172] "Clean Energy Unemployment Claims in COVID-19 Aftermath| October 2020 Unemployment Analysis," E2: Business leaders for a better environment, stronger economy, n.d., https://e2.org/reports/clean-jobs-covid-economic-crisis-october-2020/.

[173] Kurman-Faber, Tempest, and Wincele, "Building Back Better: Investing in a Resilient Recovery for Washington State."

FIGURE 24. WASHINGTON'S 2019 CLEAN JOBS BREAKDOWN



Source: E2 Clean Jobs Count 2019

ARRA kicked off unprecedented growth in clean energy jobs in the state between 2008 and 2015.[174] Since then, Washington has continued to invest in the clean energy workforce, funding efforts and institutions such as the WSU Extension Energy Program, the Pacific Northwest Center of Excellence for Clean Energy, the Smart Buildings Center, the Clean Energy Fund, the Weatherization-Plus-Health program, the Community Energy Efficiency Program, the Rural Rehabilitation Program and the Energy Efficiency and Solar Grants Program.[175, 176]

[174] Ibid.

[175] "Washington's Clean Energy Roadmap" (U.S. Department of Energy| Energy Efficiency & Renewable Energy, n.d.), https://www.energy.gov/sites/prod/files/2020/02/f71/Washington-Implementation-Model.pdf.

[176] "Workforce Development," Washington State University Energy Program, n.d., http://www.energy.wsu.edu/ResearchEvaluation/WorkforceDevelopment.aspx.

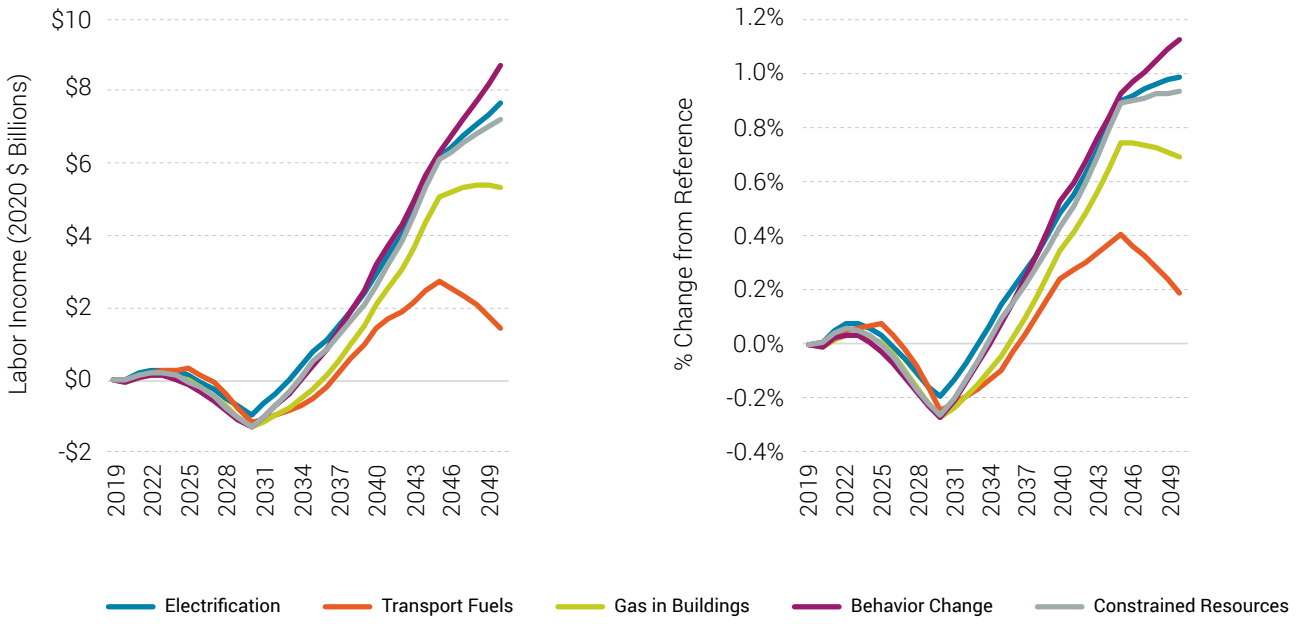
Washington's 2021 State Energy Strategy represents an opportunity to further support clean energy jobs and the state's overall workforce. Economic modeling shows that the strategy's climate and energy policies could boost employment in the 2020s and grow the workforce in the long term. The initial boost comes from investments made to build, transport, install and maintain the clean energy infrastructure needed for decarbonization. Employment takes a dip in the late 2020s and early 2030s as the economic benefits of deploying this infrastructure have yet to catch up to the costs of the energy transition. Employment would then regain speed, outperforming the Reference Scenario by as much as 1.2% (See Appendix E - Economic Impacts of Decarbonization Pathways Modeling).

Figure 25 shows the economic impact to labor income in Washington State in response to the analyzed deep decarbonization scenarios. Labor income is the sum of all household income types. These include wages and salaries, investment income and fringe benefits (mostly health insurance), adjusted for any changes in the cost of living, such as to energy prices or housing prices. The patterns for labor income are like those for employment and GDP across scenarios and through time.

Policy choices will lead to minor deviations from these predicted trends. Investments in transportation fuels leads to the greatest economic boom in the near term due to investment in manufacturing, delivering and distributing, and clean fuels statewide. However, long-term economic growth on this pathway is less than other alternatives given the higher costs to maintain clean fuel infrastructure. The Electrification and Constrained Resource Scenarios offer the greatest economic benefits over the long term. No matter the variation, each pathway increases jobs in the short- and long-term.

Current occupational and demographic trends suggest that not all workers will have an equal opportunity to compete for these jobs. The Legislature will need to pair a coherent, statewide workforce development strategy with inclusive policies that allow all Washingtonians to participate in clean energy economy.

FIGURE 25. ECONOMIC IMPACT TO LABOR INCOME IN WASHINGTON STATE



Source: Appendix E - Economic Impacts of Decarbonization Pathways, December 31, 2020 (p. 8).

6.1 Invest in Green Public Infrastructure

In Washington state, public works projects require a certain percentage of labor hours for a given construction project be performed by Washington State registered or approved apprentices (Apprenticeship Utilization Requirements).[177] From energy retrofits in public buildings to EV charging stations at state facilities, public works projects offer the opportunity to reduce emissions and generate demand for skilled apprentice labor in the clean energy economy.

Most agencies under the authority of the Governor (excluding WSDOT) must require 15% of the total labor hours to be performed by state-approved apprentices for projects estimated to cost $1 million or more. WSDOT must require 15% of the total labor hours to be performed by state-approved apprentices for projects estimated to cost $2 million or more. All public works by a school district or four-year higher education institution estimated to cost $1 million or more must contain specifications requiring that no less than 15% of the labor hours to be performed by registered apprentices.

ACTION

- Continue to invest in green public infrastructure and consider expanding labor requirements for public projects.

6.2 Invest in Reducing Emissions from State Contracts and Operations

In addition to the statewide greenhouse gas emissions limits, Washington state agencies are subject to a requirement to reduce emissions from state operations.[178] One way to support in-state industry and enlist the private sector in decarbonization is to leverage the buying power of state and local government. In 2020, Governor Inslee issued Executive Order 20-01, concerning State Efficiency and Environmental Performance.[179]

When making purchasing, construction, leasing and other decisions that affect state government's emissions of greenhouse gases or other toxic substances, agencies are explicitly directed to consider the benefits and costs, including the social costs of carbon of available options to avoid those emissions. Where cost-effective and workable solutions are available to reduce or eliminate emissions, decision makers are required select the lower-emissions options.

However, directives are not sufficient without attention to implementation. For example, the state has set requirements in Chapter 194-28 WAC for state agencies and local governments to procure alternative fuels and vehicles procurement based upon total cost of ownership and the social cost of carbon, but these rules have yet to receive the enforcement authority and administrative funding necessary for effective implementation.

Governments in Washington procure a wide range of products and services. Public contracts present opportunities to support high-quality, accessible jobs. Requiring or incentivizing suppliers and contractors to meet certain labor standards, disclose the emissions performance of their products and follow low carbon practices can support a strong workforce and further the state's progress in decarbonizing. Requiring agencies to factor greenhouse gas emissions into purchasing decisions supports and drives clean industry—leveling the field for those who have invested in green approaches and motivating others to follow suit.

ACTION

- Adopt "Buy Clean / Buy Fair" requirements for public projects.
- Ensure that existing procurement requirements and associated master contracts are supported and properly implemented.

[177] Chapter 39.04.320 RCW.

[178] (1) State agencies shall meet the statewide greenhouse gas emission limits established in RCW 70A.45.020 to achieve the following, using the estimates and strategy established in subsections (2) and (3) of this section: (a) By July 1, 2020, reduce emissions of greenhouse gases to eight hundred five thousand metric tons, or fifteen percent below 2005 emission levels; (b) By 2030, reduce emissions of greenhouse gases to five hundred twenty-one thousand metric tons, or forty-five percent below 2005 levels; (c) By 2040, reduce emissions of greenhouse gases to two hundred eighty-four thousand metric tons, or seventy percent below 2005 levels; and (d) By 2050, reduce overall emissions of greenhouse gases to forty-seven thousand metric tons, or ninety-five percent below 2005 levels and achieve net zero greenhouse gas emissions by state government as a whole. (RCW 70A.45.050).

[179] "State Efficiency and Environmental Performance," Pub. L. No. Executive Order 20-01 (n.d.), https://www.governor.wa.gov/sites/default/files/exe_order/20-01%20SEEP%20Executive%20Order%20%28tmp%29.pdf.

6.3 Invest in Washington's Clean Buildings and Weatherization Workforce Development Organizations

Washington's Green Economy Report found that a majority of Washington's clean energy sectors do not have well established workforce pipelines. The report identified 11 recommendations to develop and support workforce pipelines. In addition to those recommendations, a number of other complementary opportunities exist. One of those relates to building energy efficiency and decarbonization.

Building energy efficiency continues to be an excellent economic and climate change investment for Washington. It is the single largest clean tech employer and, according to the E2 2019 clean jobs in Washington study, demand for clean buildings and weatherization jobs are anticipated to grow as a result of market forces and public policy, i.e., the Clean Commercial Buildings Standard (Chapter 285, Laws of 2019). Additional investments in the state's buildings workforce will assist the state in meeting its climate objectives by ensuring that it has the workforce capable of accomplishing the state's energy efficiency and decarbonization objectives.

Washington has two model workforce development organizations for energy efficiency and decarbonization in the buildings sector. The Smart Buildings Center has been a regional leader in commercial building energy efficiency training and education, offering state of the art trainings in building energy efficiency and nationally recognized building operator certification program — a competency-based credentialing program for building engineers and maintenance personnel.

The Buildings Performance Center has been a leader in weatherization training and education. Employers and trainees highly recommend the Center, but also note the need for trainings to be offered more frequently and for the curriculum to be expanded. Additional funding will also be required to expand outreach and recruitment activities.[180]

The 2021 State Energy also recommends a significant market shift to heat pumps. The installation and maintenance of these heat pumps requires a skilled workforce with licenses or certifications in electrical and refrigeration management. It is in the interest of the state to ensure that it has a workforce ready to install and maintain over the medium to long-term.

ACTION

- The Legislature should invest in workforce development organizations for building energy efficiency and decarbonization. Funding should go toward the expansion of the state's existing curriculum, increasing the frequency of trainings and providing grants and stipends for

[180] Alan Hardcastle, "Weatherization Workforce Roadmap for Washington State" (Washington State University Energy Program, March 2020), https://www.commerce.wa.gov/wp-content/uploads/2020/11/Wx-Workforce-Roadmap-FINAL-March-2020-Rev-1.pdf.

[181] Ibid.

Smart Buildings Center.
Chris Limbrick/stsrealestatevisuals.com

participants in commercial and residential energy audit certifications, building operator certifications, energy management and energy code training and construction trades. Grants, stipends and trainings should be equitably advertised and offer opportunities to historically under-resourced and underrepresented communities.

- Assess labor market development needs for electrical and refrigeration licenses or certifications for heat pumps, and develop plans with the apprentice training institutions to meet those needs.

Technical trainer explaining solar panel model to students. Cavan Images/Alamy Stock Photo

6.4 Establish Accredited System of Regional Dual-Credit Career & Technical Education Programs

Washington's Centers of Excellence partner with business, industry, labor and the state's education system to create workforce pipelines for industries critical to the state's economic vitality.[182] There are currently 11 Centers of Excellence.[183] Each center specializes in one key sector of the economy.[184]

The Pacific Northwest Center of Excellence for Clean Energy serves as the state's sole Center of Excellence for clean energy.[185] Located in Centralia, Washington, the Center offers 65 community college programs in the areas of power generation, transmission and distribution; solar, wind and hydro technologies; and demand response. Students receive the skills they need to be successful in their chosen industry and externships to demonstrate and further hone their skills.[186] They graduate ready to meet the state's workforce needs and connections to industry leaders in their fields of study.[187]

As the transition to the clean energy economy accelerates, there will be a need for greater workforce development in areas not currently covered by the Pacific Northwest Center of Excellence for Clean Energy or the Smart Buildings Center. For instance, the state currently lacks a workforce pipeline for the clean transportation sector. The Centers for Excellence provide a model upon which the state can meet its workforce needs as they relate to the clean energy transition.

ACTION

- The Legislature should commission the state's Centers of Excellence to identify regional "clusters" of dual credit career and technical education (CTE) courses and funding opportunities in the clean energy sector. Each cluster should advance a degree or certification in two or more careers in clean energy.[188] The Centers of Excellence should engage under-resourced and under-represented communities in the development of their programs and recruitment policies. Grant and stipend opportunities for these communities should be part of each program.

6.5 Establish the Washington Climate Corps Program

To complement a dual-credit CTE initiative, the state should establish a comprehensive apprenticeship strategy that provides clean energy and construction training and work experience to young adults and veterans. A Climate Corps program would provide hands-on experience and community energy planning to prepare Washington communities for the clean energy transition.

[182] "About Us," Washington State Centers of Excellence, n.d., https://www.coewa.com/about.
[183] "Centers of Excellence," Washington State Centers of Excellence, n.d., https://www.coewa.com/centers-of-excellence.
[184] Ibid.
[185] "Clean Energy," Washington State Centers of Excellence, n.d., https://www.coewa.com/clean-energy.
[186] "Who We Serve," Washington State Centers of Excellence, n.d., https://www.coewa.com/who-we-serve.
[187] "Industry," Washington State Centers of Excellence, n.d., https://www.coewa.com/industry.
[188] Existing COEs representing advanced manufacturing, clean energy, maritime and IT have applied for a federal grant opportunity, but funding is not guaranteed.

King County Metro All-Electric Bus. Ned Ahrens

ACTION

- The Legislature should establish the Washington Climate Corps through the Washington Service Corps. Intermediary grants should be provided to the Centers of Excellence and Career Connect Washington to link dual-credit CTE graduates to existing registered apprenticeship programs, connect businesses to established apprenticeship programs and assist industries in establishing new apprenticeship programs when needed.

6.6 Establish a Battery-Electric Bus Fleet Training Program

To meet Washington's greenhouse gas emissions targets will require the conversion of Washington's public buses to battery electric fleets. A new and retrained workforce will be required to operate and maintain these vehicles and their supporting infrastructure.

King County Metro is the first metro area in Washington to begin planning a workforce program for battery-electric buses. In its 2020 Battery-Electric Bus Implementation Report, King County Metro identified that the transition to a battery-electric fleet will require training for battery maintenance, safety and dispatching, operator training, transit control center and service quality. Metro is currently working with the industry leaders to develop this program and coordinate and help write the training manuals to meet local transportation requirements. The report notes:

Longer term, Metro leadership needs to work closely with its operational workforce to assure a successful transition from launch to long-term operations. Metro should also be actively working with local colleges for a pipeline of required trades and competencies as electricians are going to be in high demand as transportation continues to electrify.[189]

Establishing a statewide training workforce pipeline for battery-electric fleets would provide workforce development for the whole state as the state transitions its bus fleets to battery-electric and zero-emission vehicles.

ACTION

- The Legislature should establish a workforce pipeline for the operation and maintenance of battery-electric buses and the installation and maintenance of their requisite charging infrastructure. The program should include grants and stipends for under-resourced and underrepresented communities and the operators and crewpersons of retiring fossil fuel fleets.

6.7 Prepare for a Just Industrial Transition

Even with policy intention and intervention to maintain existing industry and grow new clean industries, some Washington industries may decline over the next decades due to global or national market forces. When possible, that decline should be managed to avoid worker displacement and economic disruption. Planning a just transition is a way to decouple emissions reductions from economic opportunities for communities and workers.

Steps to enable rapid decarbonization (e.g., expedited permitting or siting) should be thoughtfully implemented

[189] "Battery-Electric Bus Implementation Report" (King County Metro, January 2020), https://kingcounty.gov/~/media/depts/metro/programs-projects/zero-emissions-fleet/battery-electric-bus-implementation-report.pdf.

so as not to create displacement, environmental damage or economic disinvestment in local communities, referred to as "sacrifice zones," often through locally unwanted land use. Tools such as the Washington Environmental Health Disparities Map[190] can help identify communities most impacted by siting a certain industry and to determine the local priorities. The permitting and siting processes must ensure meaningful participation of and representation by those most impacted in decision making.[191]

Long-term planning needs to recognize that fossil fuel use will continue to decline, with or without explicit policy. The state needs a long-term strategy for transitioning the skilled fossil fuel workforce to good-paying, skilled, clean energy jobs.

The landmark 2011 Memorandum of Understanding between the State of Washington and TransAlta to phase out the coal-fired power plant in Centralia is a successful example of a just transition. The agreement includes a commitment by TransAlta to make annual financial assistance payments to support weatherization and energy efficiency; education, worker retraining and economic development in the region (Lewis and South Thurston counties), and grants to support the deployment of clean energy technologies.[192] Under the agreement, $55 million in grant funds are overseen by three Coal Transition Funding Boards: the Weatherization Board, Economic & Community Development Board and Energy Technology Board.[193]

Unit 1 of the Centralia coal plant is slated to shut down on December 31, 2020. Unit 2 will shut down on December 31, 2025. The 15-year timeline adopted for the phaseout plan was designed to minimize job losses by allowing many employees to reach retirement age, or plan ahead to seek new employment.[194]

The state needs a long-term strategy for transitioning the skilled fossil fuel workforce to good-paying, skilled, clean energy jobs.

Over the coming decade, the fossil fuel industry is expected to lose about 140 jobs per year in Washington.[195] Prior to the COVID-19 pandemic, researchers estimated that these job losses could primarily be handled through retirement.[196] Protections for workers, such as pension guarantees,[197, 198] bridges to retirement, wage compensation insurance,[199, 200] and retraining are important for a just transition.

ACTIONS

- Identify the industries that are likely to experience transition and make a transition plan for the workers well in advance of closure. Engage industry leaders, community representatives and labor unions from the outset in mapping the priorities of each group impacted by industrial transition.
- Ensure that transition policies promote labor standards, shared benefits and long-term support for Washington industries and jobs.
- Adopt permitting and siting processes that ensure community participation and representation.

[190] "Washington Tracking Network: A Source for Environmental Public Health Data," n.d., https://fortress.wa.gov/doh/wtn/WTNIBL/.

[191] "Front and Centered Approach to Equitable Greenhouse Gas Reduction in Washington State" (Front and Centered, 2020), https://frontandcentered.org/accelerating-just-transition-in-wa-state/.

[192] "Memorandum of Agreement" (Washington Department of Ecology, December 23, 2011), https://ecology.wa.gov/DOE/files/85/858591f6-dd25-47be-ba1d-0f58264ca147.pdf.

[193] "Centralia Coal Transition Grants," n.d., https://cctgrants.com/.

[194] "TransAlta, Legislators and Environmental Groups Reach Agreement for Centralia's Transition," accessed October 26, 2020, https://www.transalta.com/our-operations/united-states/centralia/community-updates/transalta-legislators-and-environmental-groups-reach-agreement-for-centralias-transition/.

[195] Robert Pollin, Heidi Garrett-Peltier, and Jeannette Wicks-Lim, "A Green New Deal for Washington State" (University of Massachusetts Amherst, 2017), https://www.peri.umass.edu/publication/item/1033-a-green-new-deal-for-washington-state.

[196] Ibid.

[197] Jeremy Brecher, "No Worker Left Behind: Protecting Workers and Communities in the Green New Deal," New Labor Forum 29, no. 2 (May 1, 2020): 68–76, https://doi.org/10.1177/1095796020915177.

[198] Elena Foshay, Jill Kubit, and Lara Skinner, "Making the Transition: Helping Workers and Communities Retool for the Clean Energy Economy" (Apollo Alliance and Cornell Global Labor Institute, 2009), http://www.nlg-laboremploy-comm.org/media/Events_Conv2010-GreenEconCornell_ILR_Making_the_T.pdf.

[199] Robert Pollin and Brian Callaci, "The Economics of Just Transition: A Framework for Supporting Fossil Fuel–Dependent Workers and Communities in the United States," Labor Studies Journal 44, no. 2 (June 1, 2019): 93–138, https://doi.org/10.1177/0160449X18787051.

[200] Foshay, Kubit, and Skinner, "Making the Transition: Helping Workers and Communities Retool for the Clean Energy Economy."